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WIND-POWER SUPPLY FOR THE DECIMETER RANGE DIRECTIONAL RADIO SITE AT SCHÖNEBERG (EIFEL) AND THE EXPERIENCE GAINED

Report from the Central Technical Communications Office in Darmstadt

G. Rosseler, Darmstadt

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16. Abstract The Schöneberg directional radio station is located far from public power lines on a hilltop where the average wind velocity is 5.6 m/sec. The station, as first designed, required 26 kWh/day of dc power. It uses two Allgaier wind power systems, Dr. Hütter type WE/G 6, with a nominal output of 6 kW at 9 m/sec and 1 kW at 4.2 m/sec wind velocity mounted on two 10-m high tubular poles. The dc generators are differentially compounded, shunt-wound. Lead storage batteries of 110 cells and 216 Ah are used to stabilize the output and store the energy. A diesel generator system is available as an emergency system. Tests show that more than 90% of the power required for the initial unmodified communications system could probably have been supplied by the wind power system. The results were completely positive. Wind power stations are economically advantageous where it is very expensive to connect to the public power system, where adequate wind is available and especially when only a moderate amount of power is required.

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Wind-Power Supply for the Decimeter Range
Directional Radio Site at Schoneberg (Eifel)
and the Experience Gained
Report from the Central Technical Communications Office
in Darmstadt

G. Rosseler DK 621.396.43:621,311.24

With 15 pictures

Introduction

Man has tried already since the beginning of history to make use of the power of the wind in addition to the power of the water. Technology has been occupied with the task of obtaining electrical energy from wind power only for a few decennia (1, 2, 3, 4, 5). Installations for power levels up to 1200 kW have been built more or less successfully, and some have been designed on the drawing board for up to 25,000 kW (6, 7, 8). Wind power installations for nominal power levels of approximately 0.2 - 20 kW have definitely proven to be reliable. Hundreds of thousands of smaller units of up to approximately 1 kW are today in operation especially in America for power supplies for isolated farms and on islands. Direct-current, shunt-connected generators are used almost without exception in order to achieve operating voltages sufficiently constant to be useful in such installations when the strength of the wind varies within wide limits. At the same time this makes it possible to store excess electrical energy. The generators work on storage batteries connected in parallel with the consumers (9, 10). Tests with installations for feeding into a public net have also been carried out successfully many times (11, 12, 13). They are now being continued by the study /352 *

* Numbers in the margin indicate pagination in the foreign text.

group for wind power on a fully automatic unit with 100 kW alternating-current power at only 7.4 m/sec wind speed. In the following we will now report on tests carried out over several years on the wind-power current supply for a decimeter range directional radio site. An introductory paper appeared already a short time after the experimental installation was placed in operation (14).

Schöneberg relay station, which lies in the Frankfurt (Main)-Köln television radio link, occupies a special position with respect to the power supply among the decimeter stations installed until now. At this station the required electrical energy is generated from the wind, probably for the first time in directional radio operation technology. The idea then was not so much to provide a standard solution for all suitably located radio-link stations in the Federal Republic, but rather to prove that current can be supplied reliably from wind power even for such demanding devices as are being used for operating directional radio stations today.

Facts for the test

The following arguments were decisive for this test:

1. To supply this point, which is located very well for the route survey, with current from the main power net would at that time have given rise to expenses far above the average because of the long distance to the closest high-voltage lines.

2. Schöneberg, located at 670 m above sea-level, has an average /353 wind velocity of approximately 5.6 m/sec with a most frequent wind velocity of a good 4 m/sec and thereby offers very favorable conditions for producing electrical energy from wind power (figure 1 and table 1; the conditions at Nürburg are representative for Schöneberg).

The directional radio station at Schöneberg was originally planned only as a one-way through station for television. The alternating-current power requirement at that time amounted to:

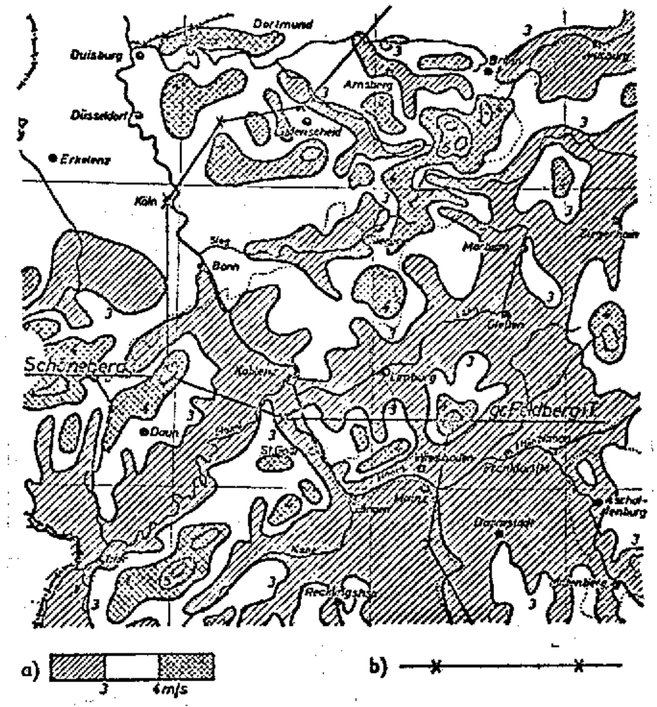

Figure 1. Section from the German weather bureau map (report No. 34, Dr. M. Manig).
a) Wind velocity in m/sec (average for the year 1943)
b) Course of the first television directional radio link.

1 Freda[1] relay station (transmitter and receiver)	900 VA
1 Television control receiver	270 VA
1 Wide-band oscilloscope	175 VA
Control devices for the power supply	100 VA
1 Charger rectifier for the diesel starter battery	150 VA
1 recording wind measuring device	230 VA
1 radio receiver	60 VA
TOTAL	1885 VA

1. The name Freda means frequency-modulated decimeter installation.

TABLE 1.* FREQUENCY OF WIND STRENGTHS AT NURBURG IN % (NOVEMBER 1946 - APRIL 1952).

Wind Strength	m/s	Jan.	Febr.	Mar.	April	May	Jun	Jul	Aug.	Sept.	Oct	Nov.	Dec	Average for the Year
0	0,0— 0,5	4,1	8,6	6,1	5,6	4,5	3,6	6,7	8,6	9,8	7,3	4,1	4,0	6,0
1	0,6— 1,7	7,0	10,4	9,1	8,5	8,2	9,8	8,0	9,0	7,1	6,2	7,8	7,5	8,2
2	1,8— 3,3	15,4	12,3	18,8	17,8	22,6	24,6	25,8	22,8	14,0	21,5	11,7	18,5	18,6
3	3,4— 5,2	18,3	18,8	17,7	20,4	30,1	30,7	30,1	31,2	30,0	26,9	18,7	22,8	24,2
4	5,3— 7,2	17,0	14,7	20,1	19,4	22,8	20,2	17,4	16,6	24,2	17,2	21,3	12,5	18,6
5	7,3— 9,8	20,1	15,5	13,8	14,1	8,0	7,6	9,7	8,4	11,3	15,1	19,0	14,3	13,3
6	9,9—12,4	10,8	12,3	8,1	10,0	3,2	3,3	1,7	2,8	1,6	5,0	10,4	11,6	7,1
7	12,5—15,3	4,8	4,7	4,3	2,4	0,6	0,2	0,4	0,4	1,8	0,2	5,0	6,1	2,8
8	15,4—18,2	2,1	2,4	1,8	1,5	—	—	0,2	0,2	0,2	0,4	2,0	2,3	1,2
9	18,3—21,5	0,2	0,2	0,2	0,4	—	—	—	—	—	0,2	—	0,2	0,1
10	21,6—25,1	—	—	—	—	—	—	—	—	—	—	—	0,2	0,0

*Table 1 and Fig. 4 were placed at our disposal by the courtesy of the German weather bureau.

The above figures are based on average daily operating time of approximately 7 hours. When one is trying to locate interference, one must count on a requirement for an additional 1 kVA for additional measuring instruments. Consequently an energy consumption of 15 kWh/day (at a cos ϕ of 0.9) must be used as a basis, which with an average overall efficiency of 0.58 corresponds to a direct-current energy of 26 kWh.

The wind-power installation

The standard Allgaier wind-power installation system, Dr. Hütter type WE/G 6, was selected to generate this energy. It has a nominal output of 6 kW, which is achieved at a wind velocity of approximately 9 m/sec. The wind starts to produce 0.3 kW power already at 3.4 m/sec, and the power reaches 1 kW at the most frequent wind velocity in the Schöneberg hill of 4.2 m/sec (Fig. 2).

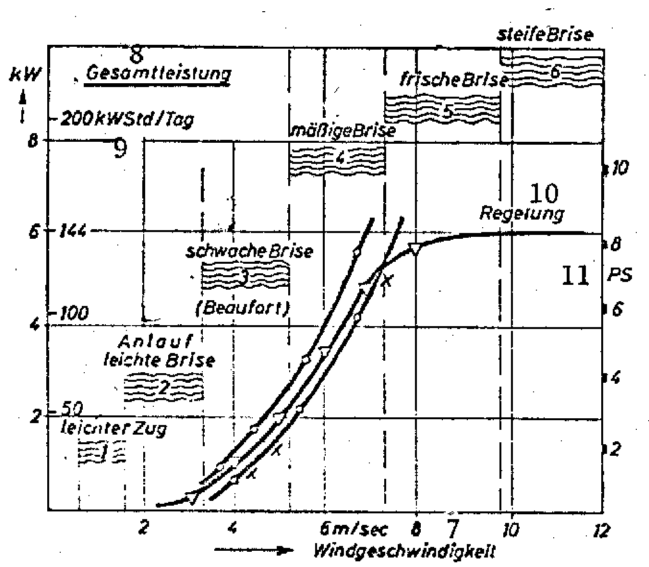

Figure 2. Power from the wind-power installation WE 10/G 6 with 10 m propeller diameter as a function of wind velocity. The range for the power to be expected for an assumed wind velocity lies between the curves indicated by circles. The values indicated by x represent power levels obtained from measurements on machine 1 on Schöneberg.
Key: 1. Faint breeze. 2. Start of light breeze; 3. Weak breeze (Beaufort); 4. Moderate breeze: 5. Fresh breeze: 6. Stiff breeze; 7. Wind velocity; 8. Total power; 9. kWh/day; 10. Regulation; 11. HP.

Two of these wind-power installations were set up in order to be able to consider a mean daily value of approximately 40 kWh as secured and especially for reasons of operational reliability. Their position with respect to each other and with respect to the operations building was, to the extent that the surface of the mountain top permitted, chosen in such a way that their own wind shadow and that of the house could have an effect only for winds with the lowest frequency for that direction (figures 3 and 4).

The wind-power engine itself is installed on a 10 m high tubular pole braced on three sides. The wind wheel consists of three narrow blades of almost 5 m length. Its axle is connected through a two-stage gear drive (1:17.5) to the axle of the flanged-on generator

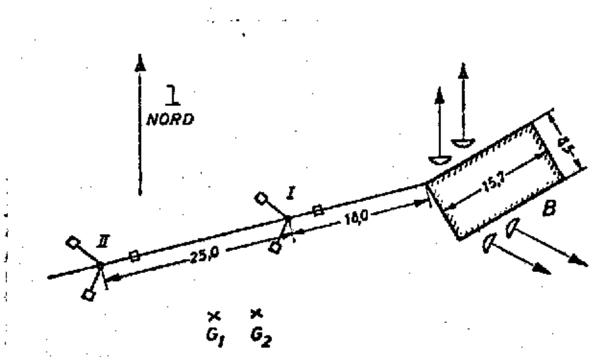

Figure 3. Location of wind-power machines 1 and 2 with respect to the operations building B and the transmitters G_1 and G_2 for the wind measurement and recording equipment. The arrows show the directional radio link.
Key: 1. North.

(figure 5a). This unit can be rotated 360° on a ball turning rim and is turned to the wind by a small lateral wind wheel with a gear ratio of 1:2223 (figure 5b). The wind-wheel blade is mounted rotatable in a holder, similar to what is used for propeller blades in aircraft, so that the driving wind can strike at various angles according to requirement. It can be adjusted in three mutually independent ways:

1. It can be adjusted manually at will by an adjustable, self-locking spindle at the mast blade. The spindle's movements are transmitted through a linkage to the control shaft of the holder.

2. It can be adjusted automatically through the centrifugal regulator, which sits on the generator shaft and acts directly on the control shaft (15). /354

3. It can be adjusted automatically through the hydraulic control independent of wind strength or of the desired generator voltage set in on the control switching board.

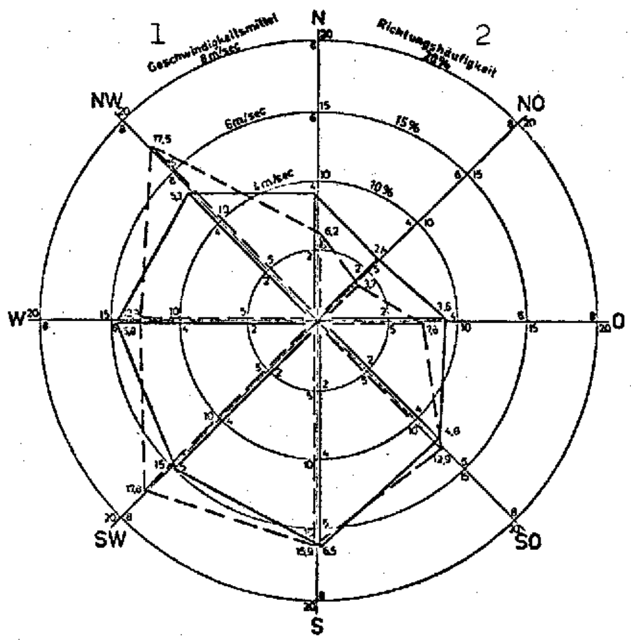

Figure 4. Wind conditions at weather station Nürburg (Eifel).
- - - - Frequency of the direction in %
——— Average wind velocity in m/sec.
Key: 1. Average velocity; 2. Frequency of direction.

The hand spindle makes it possible to choose any possible angle of incidence for the propeller blade independent of the wind conditions and thereby makes it possible to turn on and shut off the installations. In the shut-down condition the propeller blades form an angle of 0° with the direction of the wind. The blade position can be controlled automatically only when the whole or a still effective part of the control range is set free by the hand spindle.

The centrifugal regulator makes sure that the nominal speed of the propeller of 86 rpm (corresponding to 1500 rpm for the generator) is not exceeded. The 2.5 kg heavy control weight then press with considerable forces (a total of approximately 500 kg) outwards and reliably prevents the machine from reaching velocities which could damage it.

The hydraulic control is served by an oil pressure system, whose main component is an oil-pressure pump, an oil-pressure cylinder with a spring-loaded piston for controlling the guide

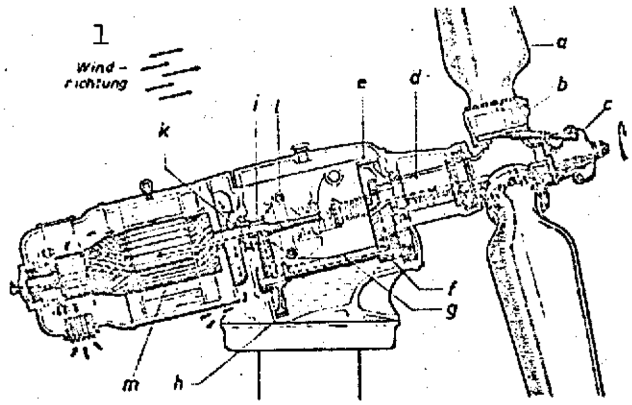

Figure 5a. Wind power engine: Internal construction (without hydraulic control).
a. blade, b. rotatable base of the blade, c. holder, d. main shaft, e. gear, f. pinion, g. intermediate shaft, h. gear wheel, i. pinion, k. generator shaft, l. centrifugal regulator, m. direct current generator.
Key: 1. wind direction.

and three valves. The control takes place in the following way:

If the unit is completely unbaffled by the hand spindle and has stopped because of the lack of wind, then the blades will in a short time be placed at such a favorable angle of incidence (start position) by a spring force so that even a weak wind is sufficient to make them rotate again slowly. The control process starts already here. The pump starts to deliver oil to the pressure cylinder and thus pushes the blade from the start position to the corresponding operating position as soon as a certain speed of rotation has been reached. When the wind strength is constant, an equilibrium condition is formed soon because just as much oil flows out through a bypass groove as can be delivered in the cylinder by the pump. However, if the speed of rotation varies in a varying wind, then more or less oil will be delivered and the angle of incidence will adapt to the new conditions through the motion of the piston.

The most important safeguard in the installation against strong wind gusts or storm is the hurricane stop valve. It is operated by a dynamic pressure disk and opens the valve when the wind strength exceeds an adjustable value. The oil pressure decreases in a few seconds whereby the blades are rotated to the

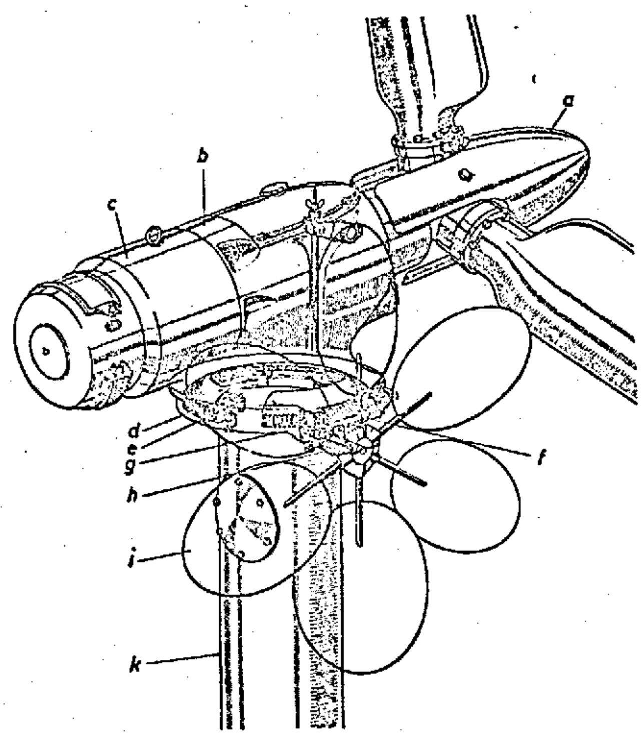

Figure 5b. Wind-power engine: external, with direction control a. protective cap for the holder, b. housing, c. direct-current generator, d. worm gear, e. ball turning rim, f. worm, g. worm gear, h. worm gear shaft, i. lateral wind wheel, k. tubular pole.

so-called feathered position in which they can even survive a hurricane without damage.

An additional oil valve, located at the armature of an electro-magnet, serves to limit the generator voltage automatically. This valve is controlled through a relay by a circuit with voltage-dependent elements. When the voltage is too high, it opens the valve only long enough until the loss in oil pressure has choked the speed of rotation sufficiently and thereby again reached the desired voltage. This arrangement works independently of the centrifugal regulator and pushes the speed of rotation of the engine down to a safer value without considering the present wind velocity when the battery is fully charged and the generator is idling.

The third oil valve is required to assist in starting up. If the plant stops slowly because of a lull in the wind, then the oil pressure in the cylinder can keep for a long time when the valves are well seated, but this means that the propeller blades are at an angle of incidence which is not favorable for start-up. In this case the start-up valve makes sure that the oil pressure is decreased and finally that the blades are placed in the start-up position by the spring forces.

The electrical installation

Both wind power installations are equipped with differentially-compounded, shunt-connected generators with interpoles of 6 kW nominal output for 220 - 310 volt direct current (figure 6). A lead storage battery of 110 cells and 216 Ah serves to stabilize the voltage and to store the energy. The energy from a fully charged battery 220 V x 216 Ah = 47.5 kWh is /355
sufficient to operate the decimeter range equipment for 12.5 hours, which corresponds to 1.8 days for the previously assumed energy requirement for seven operating hours per day or 26 kWh. Between the battery and each generator is a reverse-current relay to prevent the current from flowing back out of the battery when the generator voltage is too low. A battery switch is not being used in order to have the same condition of charge in all battery cells. The alternating-current power to operate the directional radio instrument is taken from a dc-to-ac converter. Two of these have been provided for reasons of operational reliability.

(Motor: 208/264 V dc; 29.5/23.5 A; 5.2 kW; 1500 rpm. Generator: 220 V ac; 18.2 A; cos ϕ = 0.9; 4 kVA; excitation 208/264 V.) Suitable regulator devices maintain the generated ac voltage within the limits of 220 V $\pm$ 2% even when battery voltages of 300 V occur in the necessary safety charging. The frequency variations for a generator with an 80% load lie between 49.0 and 51.5 Hz, or -2% and +3%, depending upon whether the battery is fully discharged (190 V) or has a voltage of approximately 260 V, which corresponds to a charge of approximately 85 - 90% for the charging process used. Both converters can be synchronized to permit switchover from one to the other without interruption.

Schöneberg, like all decimeter directional radio stations, also has a diesel generator set as an emergency power system. Thus one can generate electrical energy even when the wind power installations are out of operation because of lack of wind. The generating set starts automatically and charges the battery through a rectifier as soon as the battery voltage drops below 208 volts; it is switched off again automatically when the battery voltage reaches 265 V. Then it does not provide the full power of 24 kW, but only approximately 9 kW, so that the charging current does not rise above the permissible limit. The high nominal power for the diesel generating set was obtained only because a standard model was provided which is used almost exclusively for relay stations and with which one is also equipped for possible expansions at the installations.

The batteries can be charged up to 2.7 V for each cell or a total of 297 V (which corresponds to a 100% charge for the charging process used) by the emergency power system with manual control or even by the wind power installation when the wind is sufficient.

Energy for house lighting and similar purposes is taken from the battery through a carbon-pile voltage regulator, 4 - 8 kWh daily depending upon season and circumstances.

Operation and experience

A perfect summary of the course of a test can be obtained relatively easily when the test takes place under unchanged conditions from start to end. This possibility did not exist during the test of the wind power installation, since the decimeter installation had to be expanded several times during the test period.

The installation on Schöneberg was placed in operation at the end of August 1954. The daily energy requirement then amounted to an average of 26 kWh on the direct-current side. In addition to this came a daily 24 kWh for a limited time during

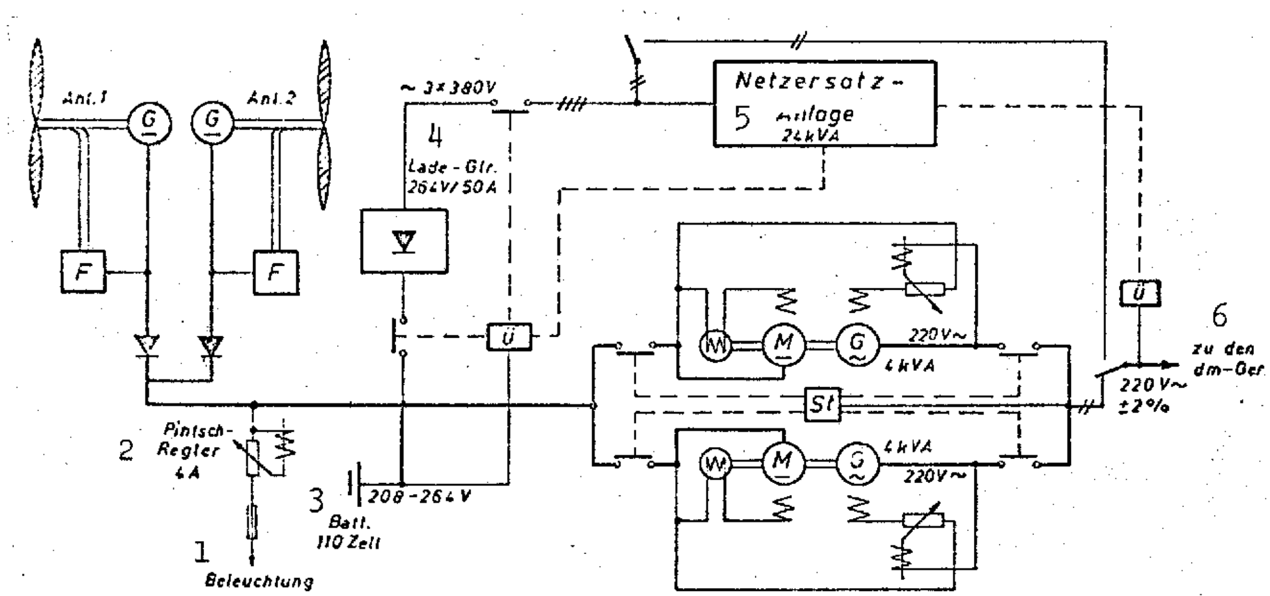

Figure 6. Wiring diagram for the power supply installation at Schoneberg. G direct-current generator in the wind power installation, F arbitrary control arrangement for the generator's exciter field, E automatic monitoring device for controlling the voltage and protecting the diesel generators and rectifiers when operating from the emergency power installation, M- and G~ direct-current motor and alternating-current generator in the converter generator unit, St control arrangement for automatic or arbitrary synchronization of the alternating-current generators for uninterrupted switchover from one generator set to another.

Key: 1. Illumination; 2. Pintsch regulator; 3. Battery 110 cells; 4. Charging rectifier 264 V/50A; 5. Emergency power system 24 kVA; 6. To the decimeter equipment.

the coldest months of the first winter. This was used to keep cooling water for the diesel engine at a favorable starting temperature since this could not yet be done by connecting to the house heating. The energy consumption had thus grown to a total of 50 kWh/day, and on most days it could be met by wind power alone.

The daily requirement for dc energy increased by additional directional radio equipment in the following steps during the test:

1. On 17 November 1955
   4 H-rack PPM 24/220 [2.] 1300 VA in continuous operation, by 48 kWh to 74 kWh,

2. On 3 July 1956.
   1 Freda branch transmitter 680 AV at 10 operating hours /256
   every day by 10 kWh to 82 kWh, and then by 8 kWh to 92 kWh when the operating time of the Freda relay station was extended to 10 hours daily,

3. On 22 October 1956.
   2 H-rack FM 60/2000 1200 VA in continuous operation, by 45 kWh to 137 kWh.

Neither the wind power installation nor the capacity of the battery was dimensioned for that type of increase in the

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[2.] H-rack contains the high-frequency equipment proper, that is transmitter and receiver without modulation and de-modulation equipment.

PPM 24/2200 signifies that the installation works with phase pulse modulation and makes it possible to transmit 24 conversations at the same time on one frequency in the 2200 MHz band.

FM 60/2000 indicates that frequency modulation is used and that the installation is able to transmit 60 conversations on a high-frequency carrier in the 2000 MHz band.

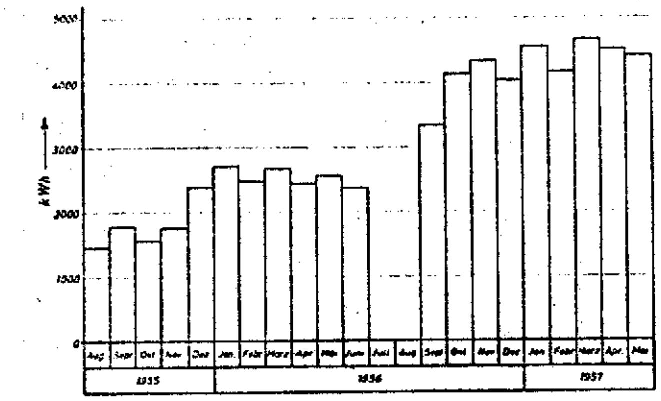
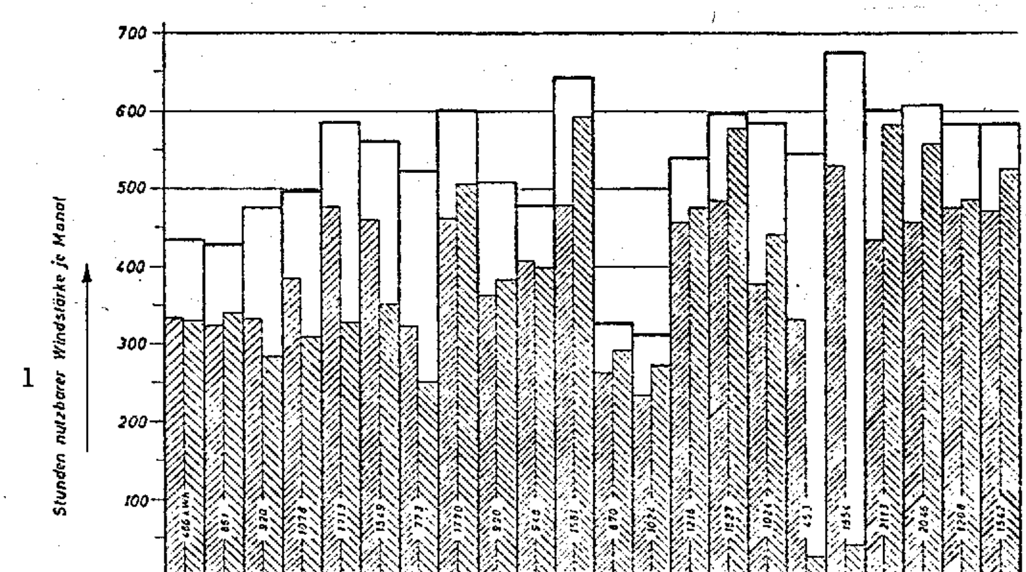


Figure 7. Total energy consumption for dm-installations, measuring equipment and house illumination and similar. (The values for the month of July and August 1956 could not be determined accurately because of modification work on the power-supply installation and have therefore been omitted.)

energy requirement (figure 7), so that an increasing portion of the energy was gradually allotted to the emergency power system. The decimeter relay stations were therefore connected to the public power supply system in the summer of 1956. The Rhine-Westfalen electric power system had shortly before built a high voltage transmission line to Schöneberg so that the cost of connecting was only 6500 DM instead of the estimated 50,000 DM for the conditions in the year 1954.

Observations during the first months of operation showed that there were no basic faults in the whole power-supply installation from the wind wheel to the dc-ac converters. Any breakdowns that occurred could in each case be ascribed to technical deficiencies and are to be considered as normal start-up problems for test installations. The contractors have eliminated these types of deficiencies within the framework of expected repair work. The power-supply system never caused any failures in the directional radio equipment.

The actual reporting time starts in the summer of 1955 when the recording measuring equipment was put into operation. Continuous line recording instruments recorded the wind parameters (velocity, paths and direction, with a fixed quantity



2 Anzahl	3 Vereisung	–	–	–	2	3	5	13	–	1	–	–	–	–	–	1	3	6	1	–	–	–	–
der 4	Abschaltung weg. voll. Batt.	2	1	10	13	15	11	1	7	4	5	9	5	4	8	4	10	6	2	14	13	6	7
Tage 5	Betrieb	31	30	31	30	31	31	29	31	30	31	30	16	19	30	31	30	31	31	28	31	30	31
6 Monat		Aug.	Sept.	Okt.	Nov.	Dez.	Jan.	Febr.	März	Apr.	Mai	Juni	Juli	Aug.	Sept.	Okt.	Nov.	Dez.	Jan.	Febr.	März	Apr.	Mai
7 Jahr		1955					1956												1957				

Figure 8. Usable supply of wind in comparison to the actual wind utilization by engines I/////// and II \\\\\\\\

Key: 1. Hours of usable wind strength each month; 2. Number of days; 3. Icing; 4. Shut off due to full battery; 5. Operation; 6. Month; 7. Year

recording device for the wind path and the direct-current energy obtained from the wind power.

Figure 8 gives information on the times for usable wind strengths and the portion of it which was actually utilized for each of the two wind-power installations. In order to give an overall picture, figure 8 also shows the days with shutdowns because of excess energy and because of icing as well as the generated number of kilowatt-hours.

All considerations and also the data the manufacturing company produced for the expected yield in kilowatt-hours for a time period of a complete year or for a full day as a function of the observed (or recorded) average wind velocity take for granted that the total wind energy available at the installation can also actually be utilized. If this is not the case, e.g., because of too small a battery, then the yield in kilowatt-hours can drop to a fraction of the possible value.

The wind available on Schöneberg could not be used exhaustively in any month. The reason for this was either that /357
energy was not required or that it was not possible to store up any more of the available energy with the relatively small battery capacity. The second reason was noticable to an increasing extent with the expansion of the directional radio station.

If the battery were twice as large (432 Ah), one would expect an average daily yield of approximately 60 kWh in contrast to the 41 kWh obtained, and this would have brought about a considerably higher efficiency for the wind-power installation. The relatively smaller load on this battery would also have the advantage that the frequency variations in the converter as a function of charging current would be decreased.

The battery used turned out to have excessive sludge formation already after one to two years. This is primarily caused by repeated overcharging of the battery for long periods of time. This drawback would also be much more unlikely to occur with a larger capacity. But an effective remedy can only be achieved by keeping constant the generator voltage on the electrical side, that is by automatic control of the exciter field, instead of control processes acting exclusively on the wind side. This can be done, for instance, in a way that has already been proven out for a long time in generators for electrical illumination in trains.

The operating timesshown under figure 8 for each of the two engines include both the hours when only a low output could be obtained because of weak wind as well as the time when the wind stength was more favorable and the generator produced full power or often even had to be choked down because there was too much energy available. How much one engine alone can produce under good wind conditions is shown by January 1957. Although in this month engine II was in operation only for 40 hours for the normal test operations and thus did not contribute appreciably to the energy generation, between 75 and 112 kWh were still reached on seven individual days.

The so-called hurricane stop valve for protecting the installation during unusually high wind strengths operated perfectly in every case.

A problem, which is probably still waiting for a perfect solution, occurs when there are persistent ice deposits. This appeared especially when the sun caused a partial thawing after strong formation of rime, and freezing then occurred again. The ice-covered blades then lost so much of their favorable profile that the generated power decreased to a small fraction. When the ice deposit is moderate, this effect is partially compensated for by the fact that during the months when rime often occurs the maximum wind strength frequency lies at higher wind velocities than during the warmer seasons (table 1). Careful attempts at knocking off or removing the ice layer were unsuccessful. The author has referred specially to this in his report "On the experience from power supply for decimeter equipment with wind power" on the annual professional convention of the wind power study group on 17 May 1957 in Göppingen. This question was covered thoroughly several times in the discussion without anybody being able to come up with an effective countermeasure.

When there was a weak wind from the east, engine I started poorly because of the wind shadow from the operations building, but this hardly affected the overall performance since the frequency of this wind direction is comparatively low. Engine II showed no detectable direction dependence.

Of the total of 15,432 hours recorded, usable wind strengths predominated in 11,680 hours, which is 75.6%. This percentage agrees well with the expected average value for the year in table 1 of approximately 73%. Engines I and II were in operation 8,864 and 8,335 hours, respectively. This is 75.9 and 71.3%, respectively, of the usable time. The energy yield is shown in figure 9.

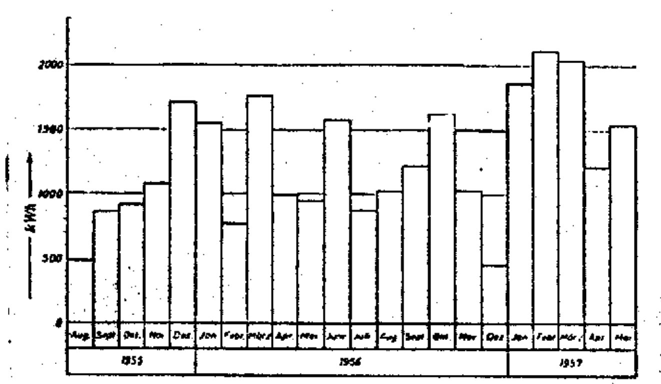


Figure 9. Electrical energy obtained from the wind power in the individual months. (During the months July and August 1956 the installations were running only for 16 and 19 days, respectively, because of modification work for connection to the public power distribution net; the low value for December 1956 is due to damage in the switching installation).

During all of the test period the consumption of electrical energy amounted to 75,550 kWh, of which 31,467 kWh or 41.7% was obtained from wind power. The larger part of the energy requirement consequently had to be supplied by the emergency power supply and later on by the public electric power net. But these numbers then give a distorted picture for evaluating the current supply on the basis of wind power, because they definitely do not correspond any more to the conditions which would be used as a basis for the original planning, as has already been explained. The figures for the year before the installation of the connection to the public electric power system, i.e., from July 1955 to June 1956, have therefore been given for comparison. They were 13,334 kWh from wind power and 12,080 kWh from the emergency power system, or a consumption of 25,416 kWh, of which 52.5% was obtained from wind power. In this year one already had to supply four H-racks PPM 24/2200 for six and a half months in addition. Finally, the first four operating months in 1954, during which the load on the power supply was in agreement with the planning, are also considered. Here the consumption of 3,328 kWh and the 2,663 kWh produced from wind power gives a proportion of 80%.

This result shows that when the amount of energy required increases during adequate wind conditions, the amount of electrical energy obtained from the wind power also increases. At the same time the already inadequate battery has thereby become less and less important as an effective energy storage and still serves only as a buffer device. If one now assumes that the initial conditions had continued to exist through the whole recording time or that there were no expansions in the directional radio installation, then the result would be a total energy requirement of only approximately 24,000 kWh for an expanded mean operating time for the Freda installations of 10 hours daily. Under the described circumstances there is actually approximately one-third more being produced, namely 31,467 kWh. /358 Consequently, there is probably no reason to doubt that with a 432 Ah battery more than 90% of these 24,000 kWh could have been obtained from wind power.

The number of days in the course of a year (from the middle of 1955 to the middle of 1956) during which certain minimum amounts of kilowatt-hours were obtained can be seen from figure 19. The curve would lie higher for a battery with higher capacity, but under otherwise unchanged conditions.

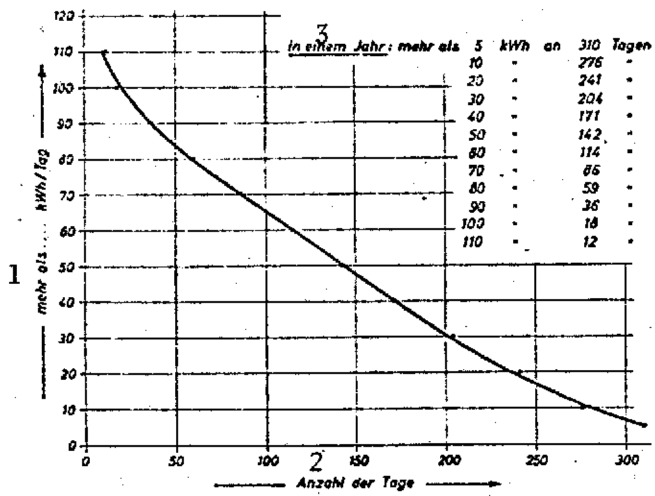


Figure 10. Number of days in the course of a year during which a certain minimum number of kilowatt hours were produced.
Key: 1. More than ... kWh/day; 2. Number of days; 3. In one year: more than 5 kWh on 310 days.

The x-marks located somewhat outside the curve in figure 2 represent the power values determined on engine I at Schöneberg as a function of wind velocity.

Special attention was given to the behavior of voltage and frequency during operation of the directional radio equipment. In order to avoid having to determine in time-consuming measurements the effect of surges in charging current on the battery voltage as well as on the voltage and frequency delivered by the converters during widely changing wind strengths, these conditions were reproduced. Charging current surges between 0 and 40 A were produced when the charger-rectifier was switched on and off. The battery voltage of 240 volts existing before these tests thereby increased a maximum of 8 V; at the same time the alternating current voltage delivered by the converter showed a deviation of ± 1 V from the 220 V nominal value and the frequency showed a maximum deviation of ± 0.5 Hz from the 50 Hz nominal value.

Even though the main purpose of this report is to explain the results of a test, a few short remarks can still be made about the profitability.

If one compares the efficiency of wind power supplies for directional radio relay stations of average dimensions at suitable points with the efficiency of supplies from a high-tension public power system, then the lower production price for each kilowatt-hours probably always favors wind power for the case of longer feedlines if only for the reason that the construction costs for the feed line, the transformer, etc., constitute a considerable part of the kilowatt-hour price with the small connected loads of such stations. Without this part the production costs for every kilowatt-hour consumed on Schöneberg since September 1957 for a withdrawal of approximately 5,000 kWh/month amounts to 18.5 pfennigs. However, if it is assumed that it costs 50,000 DM to connect up and this price is converted and applied to the kilowatt-hour price, the kilowatt-hour price increases to approximately 26 Pf. At a diesel oil price of 46 Pf per liter a kilowatt-hour from the emergency power supply costs approximately 27 Pf, where this does not consider depreciation and interest, while in each case the relay stations are equipped with an emergency power system independent of the type of current supply. Since the cost of acquisition for a wind power supply installation, as was used in this test, but with a battery of 432 Ah also amounts to approximately 50,000 DM, only the current operating costs have been added for the generated energy, so that the price per kilowatt-hour definitely lies below 10 Pf in comparison to 18.5 Pf.

In conclusion it can be said that the result of this test must be considered to be thoroughly positive and that the power supply for directional radio stations on the basis of wind power is always advantageous at places where it is excessively expensive to connect to the main public power net and where one can also register a high frequency of favorable wind strengths. This balance would be still much more favorable when one considers that in modern microwave directional radio equipment travelling-wave tubes and transistors are being used to an increasing extent instead of the previous electron tubes, because the power consumption of microwave installations can be lowered quite considerably in this way. In view of these factors further tests with wind power appear promising especially since one is starting in America to pay more attention to this type of power supply for directional radio stations because providing power is a primary problem in planning directional radio stations in areas with a wide-meshed main public power net.

The test was completed in the summer of 1957 because the wind power installations were no longer able to cover the energy requirement which had increased in an unexpected way and engine I at the operational building had to give place to an antenna tower. In addition, parallel operation with the public power net could be continued only after the operations building had been expanded since there was space neither for the larger batteries nor for the installation of new control equipment, which now could be constructed for the wind power installations instead of the control and monitoring equipment.

APPENDIX

Electrical detector elements were used for the wind measurements made in the above test. They were installed on special poles at the height of the shafts of the wind engines (figure 12). The associated display instruments were located in the operations room (figure 12).

Detectors for wind measurement installations must be mounted high and free if they are to produce perfect measurement results. They are therefore brutally exposed to all inclemencies in the weather. Two phenomena can distort the measurements or make them completely impossible. That is, on the one hand, hoar frost and ice deposits and, on the other hand, weak atmospheric discharges or even bolts of lightening which pass through the bearings of the anemometer or the wind indicator to ground. The latter case gives rise to weak burn spots in the

grease on the running surfaces of the small and sensitive /359
ball bearings and even complete scorching of the metal parts.

In order to make the wind detector elements as reliable as possible in thunderstorms, protective equipment was developed in cooperation with the Lambrecht company, Göttingen (first model in figure 13). The cup-type anemometer and the wind indicator are surrounded by two crossed ring-shaped areas of thin tubing containing heater spirals for thawing the hoar frost or the ice. Tests in the wind tunnel showed that the tubes have no measurable effects on the detector elements. A hit by lightening left heavy traces on the tubing, which was especially easy to see on the upper right half of the ring and is shown magnified in figure 14. Although the vibration when lightening struck must have been so great that a cup broke off from the anemometer, a careful examination of the detector system revealed neither the faintest trace of the passage of current on the ball bearings nor any other damage to any part of the detector element. Equipped with a new cup anemometer, the wind measuring equipment was usable again immediately.

Hoar frost deposits or icing give the weather vane and especially the cup anemometer easily such a pronounced change in the external shape that accurate measurements can no longer be obtained. It also occurred frequently that the cup anemometer and the weather vane downright froze stuck. It was therefore tried also to master the difficulties with hoar frost and icing danger with an improved model (figure 15). /360
The lightening protector rings are somewhat elliptical in shape and carry brass spikes brazed on solid on the upper half in order to avoid damage to the tubing when lightening strikes. The whole rotatable shaft, on which the weather vane sits, and also its front end can be heated in three steps. The dull, dark lacquered cup anemometer itself receives, when necessary, from above through a powerful infrared radiator so much heat that perfect measurements were possible except for rare cases of

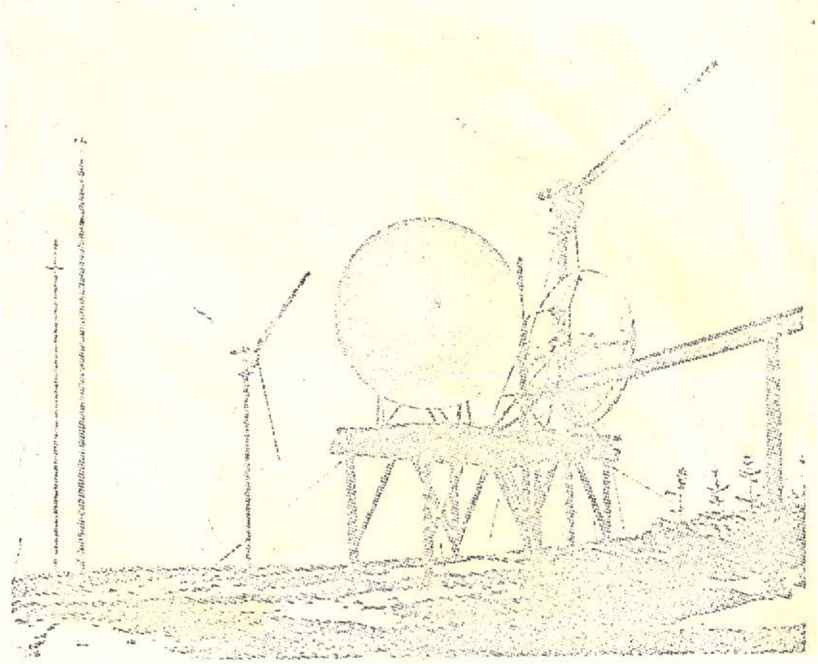


Figure 11. Both wind engines with the poles for the detector elements for the wind measuring equipment. The detector element on the left pole has been taken off for testing and shown specially in figure 15. Two parabolic antennas for the dm-links in the foreground.

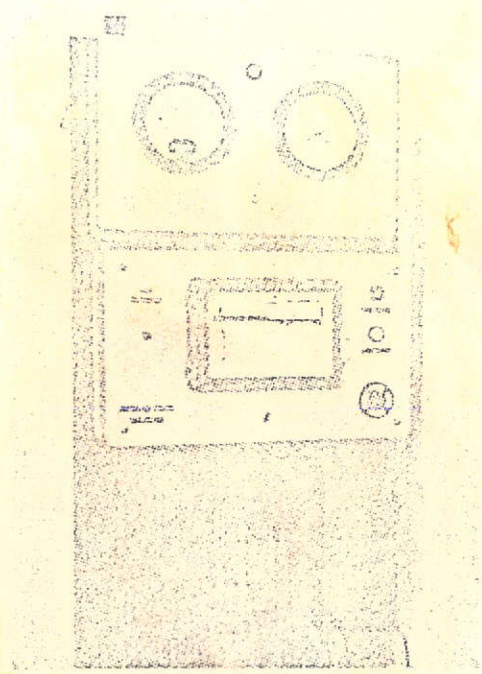


Figure 12. Rack with the wind measuring instruments; above, display of wind velocity and direction; in the middle, recorder for wind velocity, path and direction; below, reference value recording instrument for wind path and electrical energy with associated amplifiers.

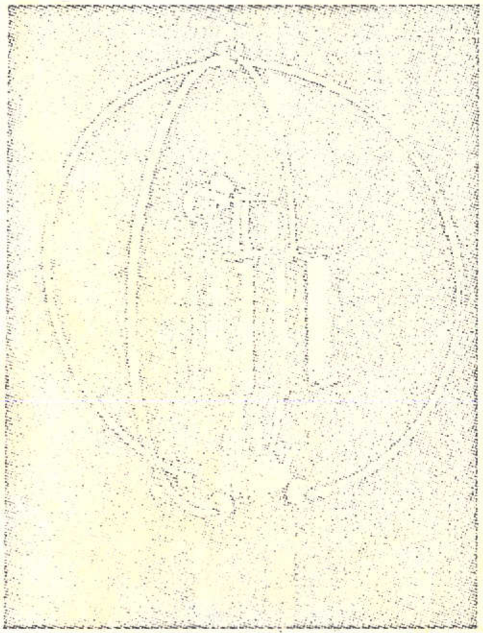


Figure 13. Detector element with heatable lightening protector.

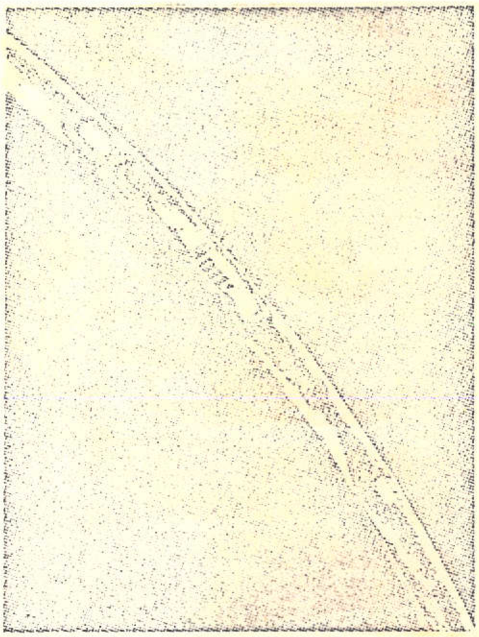


Figure 14. Tubing with molten track from being struck with lightening.

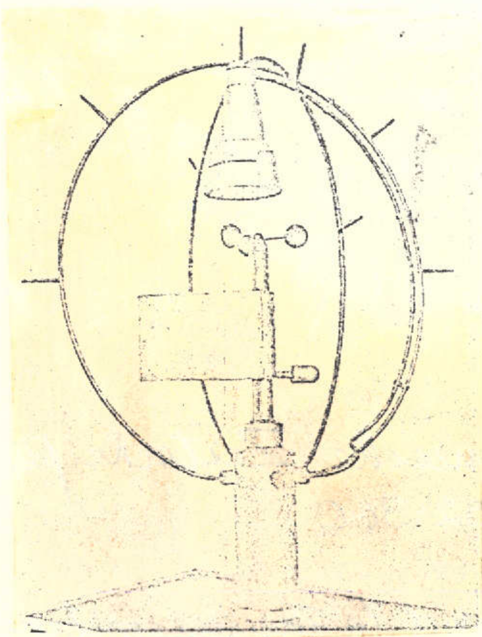


Figure 15. Latest model of the detector element with lightening and icing protection.

unusually strong ice formation. This model has proven to be very good even in thunderstorms.

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